

# Performance Analysis of Single path and Multipath Routing Protocol over Cognitive Radio ADHOC Networks

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**Abstract** — A cognitive radio is designed for the utilization of unused frequency. The transmission opportunity of a cognitive node is not guaranteed due to the presence of primary users (PUs). The performance of Cognitive Radio Adhoc Networks (CRAHNS) will significantly degrade when there are faulty nodes in the network. To provide efficient fault tolerance in the sense of faster and efficient recovery from route failure in CRAHNS, in this paper we present a single and multipath routing protocol, that uses on-demand distance vector routing, called Ad hoc On-demand Distance Vector Routing protocol (AODV) and Ad hoc On-demand Multipath Distance Vector (AOMDV) Routing Protocol. The various QOS parameters have evaluated. Since here we initially discuss about the packet transmission over number of nodes with effective end-to-end delay. We also analyze its performance using Network simulator (NS-2) software tool for the simulation purpose to give effective result of cognitive radio ad hoc networks.

**Keywords**— AODV (Adhoc On-demand Distance Vector), AOMDV (Adhoc On-demand Multipath Distance Vector), CRAHNS (Cognitive Radio Adhoc Network), Spectrum sensing, Dynamic Spectrum Access

## I. INTRODUCTION

Cognitive radio (CR) technology aims to enhance the spectrum utilization in the licensed frequencies, and also alleviate the congestion in the 2.4GHz ISM band. Recent research in this area has mainly focused on spectrum sensing and sharing issues in infrastructure-based networks that relies on the presence of a centralized entity for collecting the spectrum information, deciding the best possible spectrum for use, and allocating transmission schedules to the CR users served by it. The application of CR technology in distributed scenarios is still in a nascent stage, and several open research challenges are outlined in [1]. This project proposes a CR routing protocol for ad hoc networks (CRP) that specifically addresses the concerns of end-to-end CR performance over multiple path and the problem of protecting the PU transmissions from interference with limited knowledge of the environment. Cognitive Radio Ad-Hoc Network (CRAHNS) [1] is a new developed technology of wireless communication. The difference to traditional wireless networks is that there is no need for established infrastructure. Since there is no such infrastructure and therefore no preinstalled routers which can, for example, forward packets from one host to another, this task has to be taken over by participants, also called mobile

nodes, of the network. Each of those nodes takes equal roles, what means that all of them can operate as a host and as a router.

Traditional wireless networks are needed some improvement due to some factors such as security, power control, transmission quality and bandwidth optimization. To solve problems like maintenance and discovery of routes and topological changes of the network is the challenge of Ad-Hoc Networking. The route setup in CRP follows two stages. In the first stage, each CR user identifies the best spectrum band based on local environmental observations. Our approach permits the tried and tested modular design, wherein individual protocol implementations can function without any changes to the other layers of the network protocol stack as long as information such as the (i) physical layer transmission parameters, (ii) channel coherence bandwidth, (iii) the link layer spectrum sensing, switching times, and (iv) variance in the link throughput are written to a common memory space and made accessible to CRP.

The rest of the paper is organized as follows: Section II is related work, Section III is proposed work, Section IV Simulation & Result, and Section V is the conclusion.

## II. RELATED WORK

Recent work in the area of distributed CR routing protocols has been undertaken for (i) general ad hoc networks, and (ii) networks with specific architectural assumptions, as follows:

### A. General ad hoc networks

In the multi-hop single-transceiver CR routing protocol (MSCRP), analogous to the classical AODV, the RREQ is forwarded over all the possible channels to the destination. The protocol proposed in [9] uses a combination of routing and link scheduling to reduce intra- CR interference and spectrum switching costs. A multi-agent learning approach named adaptive fictitious play is described in [8]. The CR users exchange their channel selection information periodically that also provides information of the extent to which the different classes of traffic (delay sensitive or otherwise) on a given channel is affected. The fictitious play algorithm learns the channel decision strategies of the neighboring CR users over time to identify the channels that

are likely to be used by them. However, it is not clear how long the network would take to converge on the optimal solution, with the assurance of a stable operating point in the presence of varying PU activity.

**B. Networks with specific architectural assumptions**

The Several existing works assume knowledge of the entire topology graph, with known edge weights between any given node pair. Such an approach is seen in [6], wherein the edge weights represent the wireless capacity, and are calculated probabilistically based on interference from the PUs, the received signal strength, among others. A path-centric spectrum assignment framework (CogNet) is proposed in that construct a multi-layered graph of the network at each node such that the edge weights of the graph represent the spectrum availability between the nodes. In either case, a Dijkstra or Bellman Ford-like algorithm is run over the topology graph to find the optimal path. The dissemination of the network wide edge weights to each node incurs a prohibitive overhead, as is hence not suited for ad hoc network routing. Other works have also been proposed for mesh networks arranged in a tree hierarchy [5] [7]. Our work focuses on CR ad hoc networks, without assumptions of specific network topologies, and where each user has limited knowledge of the environment. Moreover, we believe that the consideration of the PU receivers, CR traffic classes and scalable routing approaches uniquely distinguish CRP from the other works in the literature. However, the approaches often (i) employ theoretical assumptions, such as simplified PU models, (ii) detect the PU transmitters only and not receivers, and (iii) are not guaranteed for perfect detection. Thus, while any of these methods can be used at the lower layers of the stack, we believe the network layer must also provide independently a measure of protection to the PU receivers.

**C. CRP Routing Protocol Overview**

To have communication within the network, a routing protocol is used to discover routes between nodes. The primary goal of such ad-hoc network routing protocol is to establish correct and efficient route between a pair of nodes so that messages may be delivered in a timely manner. Route construction should be done with a minimum of overhead and bandwidth consumption. The two major classifications of CRAHNs routing protocols are unipath and multipath routing protocols the route-setup in the CRP protocol is composed of two stages - (i) the spectrum selection stage, and the (ii) next hop selection stage. The source node broadcasts the RREQ over the control channel, and this packet is propagated to, the destination. Each intermediate forwarder identifies the best possible spectrum band and the preferred channels within that band during spectrum selection. The spectrum selection is based on the connectivity edges between the two nodes; selection of route depends on less number of weights of edges with specific bandwidth. The several routing protocol plays the role for the cognitive ad hoc networks. As the one of the Multipath protocol is AODMV.

**1.1) Unipath Routing Protocols**

The unipath routing protocols discover a single route between a pair of source and destination. A new route discovery is required in response to every route break which leads high overhead and latency. The two components of unipath routing protocols are i) Route Discovery: finding a route between a source and destination. ii) Route Maintenance: repairing a broken route or finding a new route in the presence of a route failure. The most commonly used unipath routing protocols are Ad Hoc On-demand Distance Vector (AODV), Dynamic Source Routing (DSR), and Destination Sequenced Distance Vector (DSDV). AODV protocol is a routing protocol in a reactive routing protocol. Routing is only when needed. Fig.1 shows message transmission using AODV protocol. Routing in a Cognitive Radio Ad hoc Network (CRAHNs) is done with the goal of finding a short and optimized route from the source to the destination node. An advantage is that smaller bandwidth is needed for maintaining routing tables, and disadvantage is it will create non negligible delay, since before using the route for a specific communication, it has to be determined. When a source has to transmit to an unknown destination sends RREQ route request for the destination. If the receiving node has not received RREQ, it is not the destination node and does not have the current route to the destination. RREP of used for hopping purpose from the source towards destination, it generates route reply (RREP).for the creation of routes between the nodes RREP is used.

Here the S is the source and D is the destination used for the transmission of simple message Hello towards destination D. When a route is needed and it is not already known by a node it sends a Route Request (RREQ) message to its neighbours. Those forward the message until it reaches the destination node. Each intermediate node updates the RREQ with its address. When a node sends a RREQ message it attaches to it a request ID. The request ID and the IP address of the node form a unique identifier. This is done in order to prevent that an intermediate node which receives twice the same RREQ message forwards it twice. When the destination receives the RREQ it sends a Route Reply (RREP) message back to the source node by reversing the hop sequence recorded in the RREQ. When the source receives the RREP it can start communicating with the destination, by including the whole route in the header of each to be sent message.

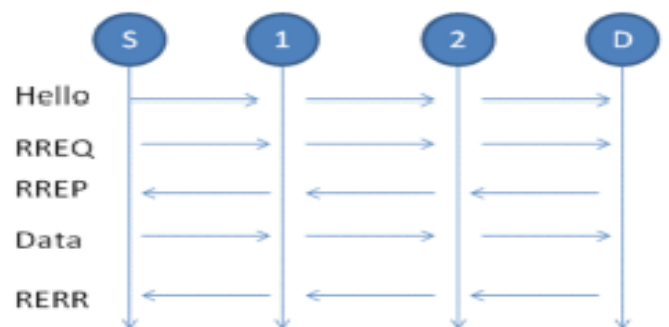


Fig. 1.AODV Protocol messaging

**1.2) Multipath Routing Protocols**

The multipath routing protocols [20] discover multiple routes between a pair of source and destination in order to have load

balancing to satisfy Quality of Service (QoS) requirements. The three main components of multipath routing protocols are

- i) Route Discovery: finding multiple nodes disjoint, links disjoint, or non-disjoint routes between a source and destination.
- ii) Traffic Allocation: Once the route discovery is over, the source node has selected a set of paths to the destination and then begins sending data to the destination along the paths.
- iii) Path Maintenance: regenerating paths after initial path discovery in order to avoid link/node failures that happened over time and node mobility.

The benefits of the multipath routing protocols are

- i) Fault tolerance: Being redundant information routed to the destination via alternative paths it reduces the probability of the disruption of communication in case of link failures,
- ii) Load Balancing: selecting diverse traffic through alternative paths in order to avoid congestion in links,
- iii) Bandwidth aggregation: Splitting the data into multiple streams and then each of which has routed through a different path to the same destination. Hence the effective bandwidth can be aggregated and
- iv) Reduced delay: In the unipath routing protocols, the path discovery process needs to be initiated to find a new route in order to avoid a route failure and this leads to high route discovery delay. This delay is minimized in multipath routing protocols by backup routes that have been identified in route discovery process. The most recently used multipath algorithms are Temporarily-Ordered Routing Algorithm (TORA), Split Multipath Routing (SMR) [14], Multipath Dynamic Source Routing (MP-DSR), Ad hoc On-demand Distance Vector-Backup Routing (AODVBR) [2] and Ad Hoc On-Demand Multipath Distance Vector Routing (AOMDV). The AOMDV protocol is widely used in wireless communication because of its edge over other protocols in various aspects, such as reducing delay, routing load [20] etc. It is an on-demand multipath routing protocol starts a route discovery procedure when needed for CRAHNS.

• **AOMDV Protocol and Routing**

Adhoc On-demand Multipath Distance Vector (AOMDV) is an extension to the Adhoc On-demand Distance vector (AODV) protocol. The main difference lies in the number of routes found in each route discovery. A little additional overhead is required for the computation of multiple paths. This protocol does not require any special type of control packets but makes use of AODV control packets with a few extra fields in the packet headers. The AOMDV protocol computes multiple loop-free and link-disjoint paths. There are three phases of the AOMDV protocol. The first phase is the Route Request, second is the Route Reply and the third phase is the Route Maintenance phase.

• **Route Request:**

The protocol propagates RREQ from source towards the destination. The figure1 will show the working of AOMDV, which allows multiple RREQ to propagate. The node S has to set a path to the destination node D. So node S in AOMDV broadcasts multiple requests to its neighbouring nodes 1 and 2. This means that request with same sequence numbers are sent to the destination node. They further broadcast the request to the other neighbouring nodes, which are further sent to the destination node D.

• **Route Reply:**

The protocol establishes multiple reverse paths both at intermediate nodes as well as destination. Multiple RREPs traverse these reverse paths back to form multiple forward paths to the destination at the source and intermediate nodes. If the intermediate nodes have the route defined for the destination then they send the RREP to the source node S. The protocol is designed to keep track of multiple routes where the routing entries for each destination contain a list of next hops together with the corresponding hop counts. All the hop counts have the same sequence number then the path with the minimum hop count is selected and all the other paths are discarded. The protocol computes multiple loop-free and link-disjoint paths. Loop-freedom is guaranteed by using a notion of “advertised hop count”.

Each duplicate route advertisement received by a node defines an alternative path to the destination. To ensure loop freedom, a node only accepts an alternative path to the destination if it has a lower hop count than the advertised hop count for that destination. The advertised hop count is generally the maximum hop count value possible for a node S to reach a node D. If any value that is received by the source S is greater than the advertised hop count value then a loop is formed so this RREP is discarded. The multiple RREPs are received by the source via multiple paths and a minimum hop count route is selected, the other routes carrying a higher hop count value are discarded.

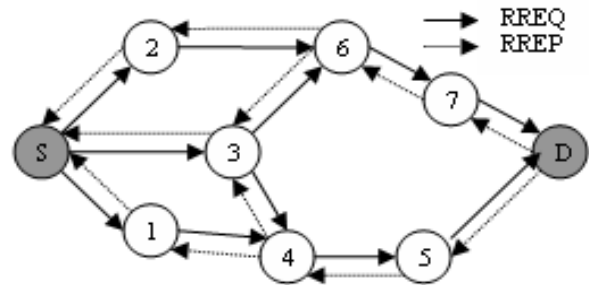


Fig. 2 Working of AOMDV

Destination is the node where the packet is destined to, the sequence number to maintain the freshness of the routes, the advertised hop count that avoids the formation of loops. The route list consists of Hop Count required to reach a particular destination, Next Hop is the next hop the packet is supposed to take to reach the required destination, and Last Hop is the last hop taken to reach the destination. If the packet is following the same path then this value is same as the Next Hop or else it changes and Expiration Timeout is the time for which the path will exist. There are multiple entries for a single destination but the routes that contain the lowest hop count are only recorded in the routing table and the other routes are discarded.

• **Route Maintenance Phase:**

The third phase is the Route Maintenance Phase. In this phase, if the intermediate nodes are not able to receive a response of the HELLO message then they broadcast a Route Error message. After receiving this message all the nodes that use the particular route to reach the destination make this

particular route as infinity and inform the source node to run a fresh route discovery. As node 3 has gone down the modified routing table of S will appear as above. When node 7 or node 5 goes down and there are no routes left in the routing table of S then the route discovery will be run. So it surely provides an improvement over AODV.

The above mechanism establishes loop free paths at every node but these paths have to be made disjoint. There are two types of disjoint paths, one is the node disjoint and the other is the link disjoint. Node-disjoint paths do not have any nodes in common, except the source and destination. The link disjoint paths do not have any common link.

An AODV protocol is been developed which develops route on-demand. The biggest drawback of AODV is with respect to its route maintenance. If a node detects a broken link while attempting to forward the packet to the next hop then it generates a RERR packet that is sent to all sources using the broken link. The source runs a new route discovery after receiving RERR packet. The frequent route breaks cause intermediate nodes to drop packets because no alternate path to destination is available. This reduces overall throughput, packet delivery ratio and increases average end-to-end delay if there is high mobility. The other drawback is that multiple RREP packets are received in response to a single RREQ packet and can lead to heavy control overhead. The HELLO message leads to unnecessary bandwidth consumption. Routing table entry structure of AOMDV as shown in table No.1.

Table No.1 AOMDV Routing table.

Destination
sequence number
advertised_hopcount
expiration_timeout
route_list {(nexthop1 , hopcount1), (nexthop2, hopcount2).....}

### III. PROPOSED WORK

In the proposed work we describe the performance of routing protocol with the spectrum selection, route discovery and route maintenance in Network layer, for that we consider the number of nodes for the cognitive adhoc networks as the primary users (PUs). One of the nodes initially considers the source node which propagates the number of nodes after some interval of time in the wireless environment. Considering the five number of nodes for the implementation, which are connected for the communication with specific channel allocation from source node to the destination node. The route request RREQ is send initially from the source node & after confirmation the Destination node send the route reply RREP. If at the destination node if the problem create the destination send the RERR message to the source node i.e. the discarding of the packets. The following is the steps for the testing the simulation based on routing protocol. The following is the procedure which is considered as our initial implementation.

1. Initialization of Spectrum selection.

2. Creation of Cognitive radio nodes in wireless scenario for the next hop selection stage with route maintenance.
3. Test the data rate transmission of a number of packets in the wireless cognitive network.
4. Using AODV and AOMDV routing protocol for the cognitive radio network data transmission.

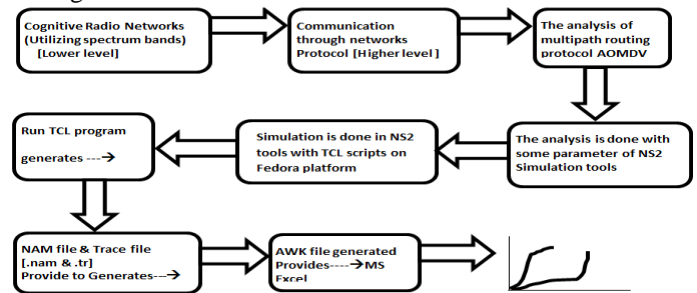


Fig.3 Block Diagram of proposed system

### IV. SIMULATION AND PERFORMANCE EVALUATION

The scope of IEEE 802.11 is to develop and maintain specifications for wireless connectivity for fixed, portable and moving stations within a local area. It defines over-the-air protocols necessary to support networking in a local area. This standard provides MAC and physical layer functionality. The Distributed Coordination Function is the primary access protocol for the automatic sharing of the wireless medium between stations and access points. IEEE 802.11 can be used in two different operating modes, infrastructure mode and independent (Ad-Hoc) mode. Following parameters are considered for the implementation of CRAHNs in NS2.

Table No.2 Parameters requirement for the network

Parameter	Value
Channel Type	Channel/Wireless Channel
Propagation	Propagation / Two way
MAC Type	MAC/802.11
Antenna Type	Antenna /Omni Antenna
Network Layer	LL
Queue	Queue/ Drop Tail/Pri Queue
Queue Length	50
Network Interface Type	Phy/wireless Phy
No. of Nodes	40
Protocol	AODV/AOMDV
Value (x)	300
Value(y)	300
Packet size	1000 bytes
Simulation Tool	Network simulator-2

#### 1. Cognitive Radio Adhoc Network

The Cognitive network consist of Primary user PU and secondary user SU described with the proposed flow chart,

with assumption of PU as even no .of nodes and SU as odd no. of nodes.

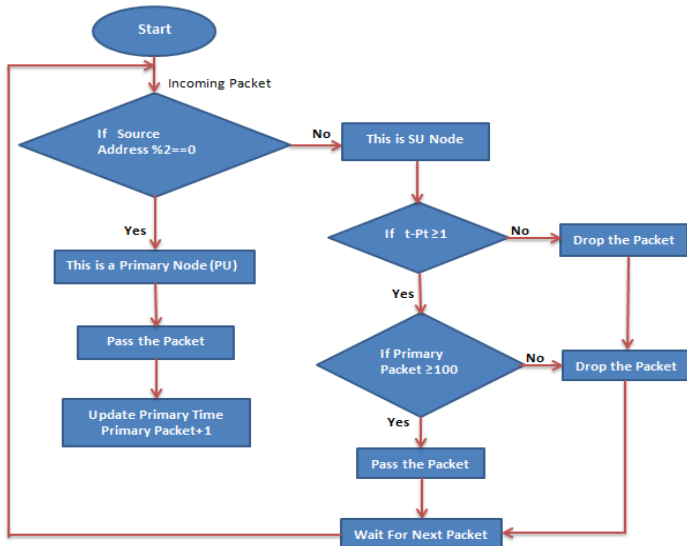


Fig. 4: Flow chat for PU& SU activity

## 2. Performance Metrics

While analysing the AODV and AOMDV routing protocol, we focused on five parameters which are Packet Delivery Ratio (PDR), Throughput, Delay, Jitter and Energy.

- **Packet Delivery Ratio (PDR):** It is the ratio which signifies the total number of packets successfully delivered to the destination.
- **Throughput:-** It is measured in terms of Packets/second. The value of throughput should be high or else it affects every service class
- **Delay:** Delay or latency could be defined as the time taken by the packets to reach from source to destination.
- **Jitter:** It could be termed as the variation in delay or packet delay variation. The value of jitter is calculated from the end to end delay. Measuring jitter is critical element to determining the performance of network and the QOS the network offers. It is the variation in the time between packets arriving. Jitter is commonly used as an indicator of consistency and stability of a network

## 3. Result Analysis

Fig.5 shows that AOMDV delivers greater percentage of oriented data.

Because of utilisation of backup paths the PDR is higher than AODV. It is observed that AOMDV deliver PDR between 99.91% to 99.98%.

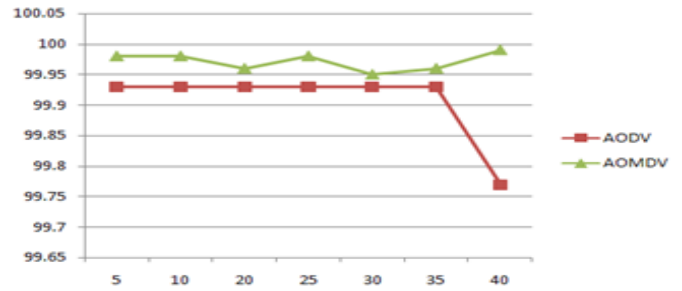


Fig.5 PDR graph (X- No.of nodes, Y-PDR in %)

The throughput analysis shown in Fig.6 which measured for 5 to 40 nodes and it is observed that at for AOMDV all maximum node throughput lies in between 54% to 72% compar to AODV

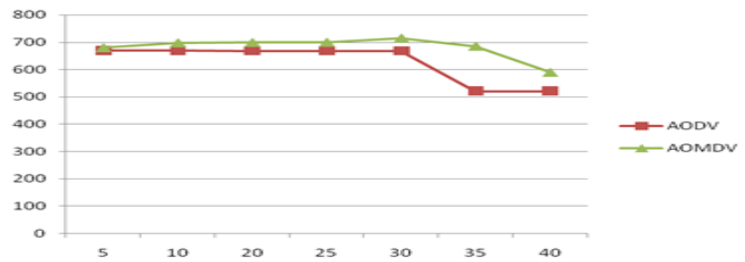


Fig.6 Throughput graph (X- No.of nodes, Y-Throughput)

The end to end delay parameter shows the capabilities of AOMDV routing protocol. Graph shows that by varying number of nodes, the end to end delay is ranging from 0.22 sec to 1.3 sec for AOMDV routing protocol.

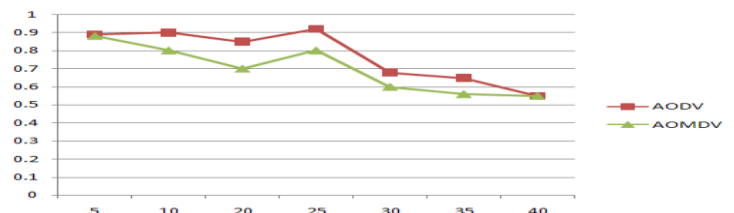


Fig. 7 Dealay graph (X-No. of nodes , Y- Delay in msec)

The graphical result shows that AOMDV protocol having more consistency and stability than AODV for CRAHNs network. The jitter is almost minimum & it is varying from 0.000221 to 0.003363 second.

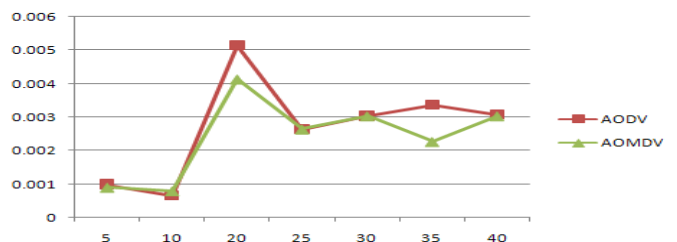


Fig. 8 Jitter graph (X- No. of Nodes, Y-jitter in m sec)

Fig9 . shows that energy consumption for AODV routing requires less energy compare to AOMDV for the number of nodes.

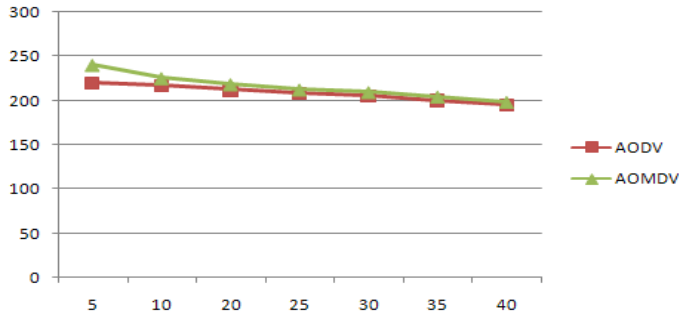


Fig.9 Energy graph (X-No. of Nodes, Y- Energy in Jule)

## V.CONCLUSION

The routing protocol AMODV gives the better performance as the spectrum selection stage & multipath selection stage in the cognitive radio ad hoc networks. For single path routing AODV having less energy consumption. The output shows that the packet received, packet loss provides the efficiency of AOMDV protocol as multiple routes being discovered and the route carrying the minimum hop count value is selected in CRANHS. In future we have to analyze the other traffic types such as TCP with comparative graphs. Results shows that AOMDV has better efficiency in case of throughput jitter and delay with stable connectivity.

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